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EVALUATION OF UNION CARBIDE CORPORATION  
EPOXY BINDER FOR USE  
IN AIRCRAFT PARACHUTE FLARES



PREPARED BY

RESEARCH AND DEVELOPMENT DEPARTMENT  
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EPOXY BINDER FOR USE  
IN AIRCRAFT PARACHUTE FLARES

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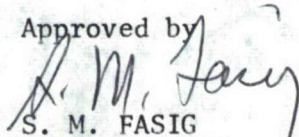


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## ABSTRACT

The material used as a binder in the pyrotechnic compositions (candles) of Mk 24 and Mk 45 Aircraft Parachute Flares, since the 1968 conversion from Laminac to epoxy, has been procured on a sole-source basis from the Dow Chemical Company. A thorough analysis of all pertinent properties of an epoxy produced by Union Carbide Corporation has demonstrated that this material is, in all significant respects, as good as that obtained from Dow. This report recommends that Union Carbide Corporation be approved as an alternate supplier for the epoxy used in these flare candles.

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EVALUATION OF UNION CARBIDE CORPORATION  
EPOXY BINDER FOR USE IN AIRCRAFT PARACHUTE FLARES

1. Background.

a. This study was undertaken for the express purpose of evaluating the epoxy binder material produced by and available from the Union Carbide Corporation. Since 1968, the Dow Chemical Company has been the designated sole supplier of epoxy binder used in production of illuminating candle composition for Mk 24 Mod 4 and Mk 45 Mod 0 Aircraft Parachute Flares. There is an obvious advantage to the Government in having two or more suppliers on a competitive basis.

b. The Union Carbide Corporation supplied the binder for the evaluation tests reported herewith and quoted a price for large-quantity procurement which is significantly lower than the price being paid for the presently used epoxy.

2. Chemical Description of Union Carbide Epoxy. The epoxy binder material produced by Union Carbide Corporation consists of a two-part system--resin and hardener. These two prime constituents are described as follows:

a. Resin. The resin, which is identified as ERLA-2713, is a diepoxide which has been modified for low viscosity. It is a reactive diluent, general purpose-type liquid. The reactive diluent, approximately 20% by weight, is CGE (cresylglycidyl ether), and the resin is based upon the reaction of bisphenol-A and epichlorohydrin to produce diglycidyl ether of bisphenol-A as the major constituent. The epoxy equivalent weight range of 185-195 and low viscosity of 500-700 cps is practically the same as used in the present production binder resin,

Dow's DER-321.

b. Hardener. The curing agent or hardener, identified as ZZLA-0672, is a moderately low viscosity, aliphatic polyamine with an amine hydrogen equivalent weight of 104.5. The epoxy resin is cured with this reactive crosslinking agent TETA(triethylene tetramine) which has been modified by the addition of a nonreactive diluent, mobilsol-44, for improved flexibility. This amine hardener is a room-temperature-curing type which makes the application of heat unnecessary; however, a short post cure at high temperature (100°C) will improve the properties of the cured binder. To obtain optimum properties and to insure complete cure of the resin, it is desirable to react the resin and curing agent at approximate stoichiometric quantities. To determine the ratio of resin to hardener, calculations were made as follows:

$$\text{*Phr of hardener (0672)} = \frac{\text{Amine H eq. wt.} \times 100}{\text{Epoxy eq.wt.}}$$

$$\text{Phr (0672)} = \frac{(104.5)(100)}{190} = 55.0$$

Therefore the mixing ratio which is used for this binder system is 100 Phr of ERL-2713 to 55 Phr of ZZLA-0672.

3. Items evaluated. The following items and materials were tested during this evaluation:

a. Complete flare candles made for candlepower, burn time, temperature and humidity, vibration, and pressure buildup tests.

b. Separate binder constituents (resin and hardener) for vapor pressure and compatibility tests.

c. Cured Dow and Union Carbide epoxy for physical properties determination and migration tests.



4. Candle formulations. Table I gives the formulations of candle compositions containing both 3.5% and 4% binder material. The six separate formulas resulted from varying the magnesium content of the batches. Table II shows the results of burn time and candlepower tests that were conducted using candles that were made from these six formulas as well as those made from the standard Mk 24 and Mk 45 formulas. It is readily seen from Table II that candles made with Union Carbide and standard, that is, presently used epoxy binders, are virtually equal from the standpoint of candlepower. The relative intensity of the light energy output varies in direct proportion with the percentage of magnesium in the formula. Thus, the total formulation has to be taken into account in comparing the test data. Formula "C" has the same magnesium content as the control candles. In T&H testing, it was noted that the loss in burn time, which is characteristic of this type of testing, was significantly less in the Union Carbide candles than it was in the control candles. Table III shows that the Union Carbide candles had a variation of only 3 to 5 seconds, whereas the burning time of the control candles varied 10 to 12 seconds after T&H cycling.

5. Gas Generation Test. A pressure buildup-type test was conducted by placing the test candles in sealed tubes with pressure gages attached to their tops. These tubes were then placed in a temperature-controlled chamber which was set at 140°F. The gages were read and the data recorded each day for 10 days with results as shown in Table IV. This data indicates that the Union Carbide candles generated an average pressure of 3.25 psi as compared with 3.125 psi average for the control candles. The primary significance here is not in the comparison of one



epoxy with another; however, it is indicative of the desirability of epoxy from whatever source. This relatively low generation of hydrogen is an excellent property of the epoxies - they provide good protection which effectively prevents absorption of water into the flare composition.

6. Compatibility Factors. The separate chemical constituents of the Union Carbide epoxy; that is, the resin and the hardener, proved to be totally compatible with other flare components with which they might come into contact. There developed, however, a cause for some concern in respect to the nonreactive diluent, Mobilsol-44, which is simply a long-chained hydrocarbon compound that is added to the Union Carbide hardener to increase flexibility. Since this ingredient does not react in the fully cured system, it was feared that there might be a possibility of its separating from the binder through evaporation at higher temperatures. A vapor-pressure test was conducted on the diluent to investigate this possibility. The pressure was determined over a temperature range of from 150°F to 324.5°F as shown below. (No measurable pressure was obtained at temperatures below 150°F). A vapor pressure buildup of 6.6 mm of mercury at 190°F is considered to be acceptably low for illuminating flare applications.

| <u>Temperature °F</u> | <u>Vapor Pressure, Torr</u> |
|-----------------------|-----------------------------|
| 150                   | 3.5                         |
| 190                   | 6.6                         |
| 260                   | 17.0                        |
| 324.5                 | 26.0                        |

7. Physical Properties. The physical properties that were investigated showed a wide variation between the two binder systems. Table V clearly demonstrates the very pronounced differences in elasticity. The Union Carbide epoxy is rubbery and quite flexible, whereas the epoxy obtained



from the Dow source is comparatively rigid and brittle. This, of course, accounts for the rather extreme differences in tensile strength and stretching properties as shown in Table V. This elasticity in the Union Carbide product results from the inclusion in its hardener formulation of the nonreactive diluent. Mobilsol-44 was added for the express purpose of achieving the flexibility that was noted. Such flexibility, however, is gained at the expense of tensile and impact strength. The chief requisites for a nonreactive diluent are (1) that it not foam or vaporize during the curing process, and (2) that it not migrate from the fully cured composition.

a. Migration Tests. The Quality Evaluation Department at Crane conducted migration tests on the cured Union Carbide binder material. In these tests, an attempt was made to measure the rate of migration of volatiles from the cured binder at a temperature of 158°F. This test would show if any of the nonreactive diluent, which is not tied up in the cured resin structure, comes out of the cured system. The test consisted of using a 1" block of cured resin against a 1" block of steel with a porous asbestos paper disc sandwiched in between. The asbestos discs were carefully weighed and on some control units a drop of Mobilsol-44 was added. During the tests the control samples lost their charge of Mobilsol-44 and when the asbestos discs were reweighed, no difference in weight could be detected. Therefore, it could not be determined if any of the nonreactive diluent came out of the system and evaporated, or remained intact. Since thermal degradation tests were in progress, it was decided not to rerun the migration tests as these tests would show the loss of weight of the cured resin which would indicate



any evaporation of the nonreactive diluent.

b. Thermal Degradation Tests. Table VI gives detailed results of thermal degradation tests which were conducted on both the Union Carbide epoxy and the Dow epoxy presently used in flares. It was evident that these tests would show any migration of the nonreactive diluent out of the Union Carbide system and thus supply the information that was unobtainable through the migration tests. Cured binders were tested at 75°C, 100°C, and 160°C. As Table VI shows, the diluent exuded at 75°C (167°F) with a weight loss of approximately 2%. This increases as the temperature is raised to 160°C. Since the diluent constitutes 30 to 33 percent of the Union Carbide binder weight, a loss of the magnitude of 2% at 167°F is considered to be not harmful. The weight loss in the control epoxy system was .5 to 1.0 percent at 75°C which indicates that a nonreactive diluent is present in this system also. Neither of the epoxies foamed during the curing process.

8. Conclusions. A binder's main purpose in illuminating flare compositions is to provide a bond for holding the fuel and oxidizing constituents of the candle together. It should also have the desirable properties of insulating against moisture absorption, of increasing the quantity of mix per volumetric unit, of regulating to a degree the candle's burning time, and of acting as a wetting agent to desensitize the magnesium during the mixing process. The Union Carbide epoxy binder amply satisfies all of these requirements. While it proved to be physically weaker than the presently used epoxy, its strength is more than adequate for the intended purpose since candles are consolidated under high pressure into heavy cardboard tubes which aid greatly in holding the ingredients together.

The greater flexibility of the Union Carbide product should, it is believed, add to its value as a binder by reducing the tendency of candle composition to "chunk out" during burning. The Union Carbide epoxy showed improvement over the presently used binder in that it exhibited a more controllable burning rate. It is also readily available at a lower cost.

9. Recommendation. It is recommended that the Union Carbide Corporation be approved as an alternate supplier of binder epoxy for the Mk 24 and Mk 45 Aircraft Parachute Flare production and that the drawings for both of these flares be amended to include the Union Carbide epoxy as an alternate binder material.



TABLE I  
Candle Formulations Containing Union Carbide Epoxy

|                                   | <u>Formulas</u> |        |        |       |       |       |
|-----------------------------------|-----------------|--------|--------|-------|-------|-------|
|                                   | A               | B      | C      | D     | E     | F     |
| Used for Test Candles Nos.        | 1-36            | 40-46  | 50-56  | 57-79 | 80-86 | 90-96 |
| Magnesium Weight (in pounds)      | 70              | 71.25  | 72.5   | 70    | 71.25 | 72.5  |
| Magnesium Percentage              | 56%             | 57%    | 58%    | 56%   | 57%   | 58%   |
| Oxidizer Weight (in pounds)       | 50.625          | 49.375 | 48.125 | 50    | 48.75 | 47.5  |
| Oxidizer Percentage               | 40.5%           | 39.5%  | 38.5%  | 40%   | 39%   | 38%   |
| Binder Percentage                 | 3.5%            | 3.5%   | 3.5%   | 4%    | 4%    | 4%    |
| Binder Resin Weight (in grams)    | 1,281           | 1,281  | 1,281  | 1,460 | 1,460 | 1,460 |
| Binder Hardener Weight (in grams) | 705             | 705    | 705    | 805   | 805   | 805   |

∞

NOTE: Control candles were standard Mk 24 and Mk 45 components. For purpose of these tests (see Table II), they were numbered 100 and above.



TABLE II  
Static Functioning Test

| <u>FORMULA A CANDLES</u> |             |                  | <u>FORMULA B CANDLES</u> |             |                  |
|--------------------------|-------------|------------------|--------------------------|-------------|------------------|
| Candle No.               | Candlepower | Burn Time (sec.) | Candle No.               | Candlepower | Burn Time (sec.) |
| 12                       | 1,837,500   | 204.0            | 44                       | 1,819,500   | 208.0            |
| 23                       | 1,791,000   | 204.0            | 43                       | 1,845,500   | 209.0            |
| 28                       | 1,636,000   | 206.0            | 40                       | 1,681,500   | 207.0            |
| 6                        | 1,789,500   | 210.0            | 41                       | 1,824,000   | 209.0            |
| 15                       | 1,884,500   | 209.0            | 46                       | 1,870,500   | 210.0            |
| Average                  | 1,787,700   | 206.6            |                          | 1,808,200   | 208.6            |
| Control Candle Avg.      | 1,865,900   | 204.2            |                          | 1,865,900   | 204.2            |

| <u>FORMULA C CANDLES</u> |             |                  | <u>FORMULA D CANDLES</u> |             |                  |
|--------------------------|-------------|------------------|--------------------------|-------------|------------------|
| Candle No.               | Candlepower | Burn Time (sec.) | Candle No.               | Candlepower | Burn Time (sec.) |
| 53                       | 1,884,000   | 203.8            | 68                       | 1,760,500   | 223.0            |
| 51                       | 1,820,500   | 205.5            | 74                       | 1,726,000   | 225.0            |
| 56                       | 1,798,000   | 202.0            | 57                       | 1,600,000   | 225.0            |
| 52                       | 1,859,000   | 205.0            | 63                       | 1,698,000   | 221.0            |
| 54                       | 1,969,500   | 205.0            | 67                       | 1,827,000   | 225.0            |
| Average                  | 1,866,200   | 204.0            |                          | 1,722,300   | 223.8            |
| Control Candle Avg.      | 1,865,900   | 204.2            |                          | 1,865,900   | 204.2            |

TABLE II (cont.)  
Static Functioning Test

| <u>FORMULA E CANDLES</u> |             |                  | <u>FORMULA F CANDLES</u> |             |                  |
|--------------------------|-------------|------------------|--------------------------|-------------|------------------|
| Candle No.               | Candlepower | Burn Time (sec.) | Candle No.               | Candlepower | Burn Time (sec.) |
| 86                       | 1,920,500   | 193.0            | 90                       | 1,914,500   | 204.0            |
| 81                       | 1,934,500   | 198.0            | 93                       | 1,859,000   | 210.5            |
| 80                       | 1,784,000   | 195.0            | 92                       | 1,666,500   | 218.0            |
| 85                       | 1,856,500   | 202.0            | 94                       | 1,807,000   | 211.0            |
| 82                       | 2,093,000   | 200.0            | 95                       | 1,894,500   | 212.0            |
| Average                  | 1,917,700   | 197.6            |                          | 1,828,300   | 211.1            |
| Control Candle Avg.      | 1,865,900   | 204.2            |                          | 1,865,900   | 204.2            |

CONTROL CANDLES

| Candle No. | Candlepower | Burn Time (sec.) |
|------------|-------------|------------------|
| 108        | 1,878,000   | 205.0            |
| 109        | 1,824,000   | 206.0            |
| 110        | 1,840,000   | 194.0            |
| 111        | 1,898,000   | 202.0            |
| 112        | 1,889,500   | 214.0            |
| Average    | 1,865,900   | 204.2            |



TABLE III  
Static Tests Before And After T&H Conditioning

FORMULA A CANDLES

| <u>Not Conditioned</u> |             |           | <u>After 14-Day T&amp;H</u> |             |           |           |
|------------------------|-------------|-----------|-----------------------------|-------------|-----------|-----------|
| Candle No.             | Candlepower | Burn Time | Candle No.                  | Candlepower | Burn Time | Variation |
| 2                      | 1,896,000   | 210.0     | 8                           | 1,853,000   | 205.0     | -5 sec.   |
| 21                     | 1,825,500   | 208.0     | 32                          | 1,849,500   | 202.0     | -6 sec.   |
| 30                     | 1,867,500   | 204.0     | 16                          | 1,917,500   | 204.0     | -0 sec.   |
| 35                     | 1,817,500   | 210.0     | 27                          | 1,886,500   | 203.0     | -7 sec.   |
| 7                      | 1,805,000   | 209.0     | 1                           | 1,850,000   | 210.8     | +1.8 sec. |
| 17                     | 1,899,000   | 207.0     | 20                          | 1,883,500   | 205.0     | -2 sec.   |
| Averages               | 1,851,750   | 208.0     |                             | 1,873,333   | 204.977   | -3 sec.   |

FORMULA D CANDLES

| <u>Not Conditioned</u> |             |           | <u>After 14-Day T&amp;H</u> |             |           |            |
|------------------------|-------------|-----------|-----------------------------|-------------|-----------|------------|
| Candle No.             | Candlepower | Burn Time | Candle No.                  | Candlepower | Burn Time | Variation  |
| 62                     | 1,749,500   | 219.0     | 75                          | 1,716,500   | 217.0     | -2 sec.    |
| 73                     | 1,696,500   | 226.0     | 72                          | 1,837,000   | 222.0     | -4 sec.    |
| 60                     | 1,707,000   | 224.0     | 59                          | 1,704,000   | 212.6     | -11.4 sec. |
| 70                     | 1,802,500   | 225.0     | 65                          | 1,717,500   | 222.0     | -3 sec.    |
| Averages               | 1,738,875   | 223.5     |                             | 1,743,750   | 218.4     | -5.1 sec.  |

TABLE III (cont.)  
Static Tests Before And After T&H Conditioning

| <u>CONTROL CANDLES</u> |             |           |                             |             |           |            |
|------------------------|-------------|-----------|-----------------------------|-------------|-----------|------------|
| <u>Not Conditioned</u> |             |           | <u>After 14-Day T&amp;H</u> |             |           |            |
| Candle No.             | Candlepower | Burn Time | Candle No.                  | Candlepower | Burn Time | Variation  |
| 102                    | 2,151,500   | 199.0     | 100                         | 2,075,000   | 182.0     | -17 sec.   |
| 103                    | 2,020,500   | 201.0     | 101                         | 2,044,500   | 193.0     | -8 sec.    |
| Averages               | 2,086,000   | 200.0     |                             | 2,059,750   | 187.5     | -12.5 sec. |



TABLE IV  
Pressure Build-Up Test

Union Carbide Epoxy Candles

Daily Pressure Measurements (psi)

| Candle No. | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | 10th |
|------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| 4          | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 1   | 3    |
| 10         | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 1   | 2    |
| 25         | 5   | 4   | 4   | 3   | 4   | 4   | 3   | 5   | 5   | 6    |
| 31         | 2   | 1   | 0   | 0   | 1   | 1   | 1   | 2   | 3   | 4    |
| 42         | 4   | 2   | 1   | 1   | 2   | 2   | 2   | 3   | 4   | 4.5  |
| 45         | 3   | 1   | 1   | 0   | 0   | 0   | 0   | 1   | 2   | 4    |
| 50         | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 1   | 3    |
| 55         | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0    |
| 64         | 3   | 2   | 1   | 0   | 1   | 1   | 1   | 2   | 2   | 4    |
| 69         | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 1    |
| 83         | 3   | 2   | 2   | 1   | 3   | 3   | 3   | 5   | 6   | 7    |
| 84         | 2   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 1   | 3    |
| 91         | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 1   | 1   | 3    |
| 96         | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 1    |

Average 10th Day Pressure 3.25

Standard Mk 45 Candles

Daily Pressure Measurements (psi)

|     |   |   |   |   |   |   |    |   |   |     |
|-----|---|---|---|---|---|---|----|---|---|-----|
| 104 | 1 | 0 | 0 | 0 | 0 | 0 | .5 | 2 | 3 | 4   |
| 105 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 1   |
| 106 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 1 | 1 | 3   |
| 107 | 3 | 2 | 1 | 0 | 1 | 1 | 1  | 2 | 3 | 4.5 |

Average 10th Day Pressure 3.125

TABLE V  
Tensile Strength Test

| Epoxy         | Breaks at (psi) | Elongation (%) |
|---------------|-----------------|----------------|
| Dow           | 3300            | 11             |
| Union Carbide | 610             | 60             |

TABLE VI  
Thermal Degradation Test

| Epoxy         | Sample | % Wt. Loss<br>@ 75°C | % Wt. Loss<br>@ 100°C | % Wt. Loss<br>@ 160°C |
|---------------|--------|----------------------|-----------------------|-----------------------|
| Control (Dow) | 1      | .5 - 1.0             | 1.0 - 2.0             | 2.0 - 10.0            |
| Control (Dow) | 2      | .5 - 1.0             | .5 - 1.0              | 2.0 - 10.0            |
| Control (Dow) | 3      | .5 - 1.0             | .5 - 1.0              | 2.0 - 10.0            |
| Control (Dow) | 4      | .5 - 1.0             | .5 - 1.0              | 2.0 - 10.0            |
| Control (Dow) | 5      | .5 - 1.0             | .5 - 1.0              | 2.0 - 10.0            |
| Control (Dow) | 6      | 1.0 - 2.0            | 1.0 - 2.0             | 10.0 - 15.0           |
| Control (Dow) | 7      | 1.0 - 2.0            | 1.0 - 2.0             | 15.0 - 20.0           |
| Control (Dow) | 8      | .5 - 1.0             | 1.0 - 2.0             | 10.0 - 15.0           |
| Control (Dow) | 9      | .5 - 1.0             | 1.0 - 2.0             | 2.0 - 10.0            |
| Control (Dow) | 10     | 1.0 - 2.0            | 1.0 - 2.0             | 10.0 - 15.0           |
| Union Carbide | 1      | 2.0 - 10.0           | 15.0 - 20.0           | 20.0                  |
| Union Carbide | 2      | 2.0 - 10.0           | 20.0 - 20.0           | 20.0                  |
| Union Carbide | 3      | 2.0 - 10.0           | 10.0 - 15.0           | 20.0                  |
| Union Carbide | 4      | 2.0 - 10.0           | 10.0 - 15.0           | 20.0                  |
| Union Carbide | 5      | 2.0 - 10.0           | 10.0 - 15.0           | 20.0                  |
| Union Carbide | 6      | 2.0 - 10.0           | 10.0 - 15.0           | 20.0                  |
| Union Carbide | 7      | 2.0 - 10.0           | 10.0 - 15.0           | 20.0                  |
| Union Carbide | 8      | 2.0 - 10.0           | 10.0 - 15.0           | 20.0                  |
| Union Carbide | 9      | .5 - 1.0             | 2.0 - 10.0            | 20.0                  |
| Union Carbide | 10     | 2.0 - 10.0           | 2.0 - 10.0            | 20.0                  |

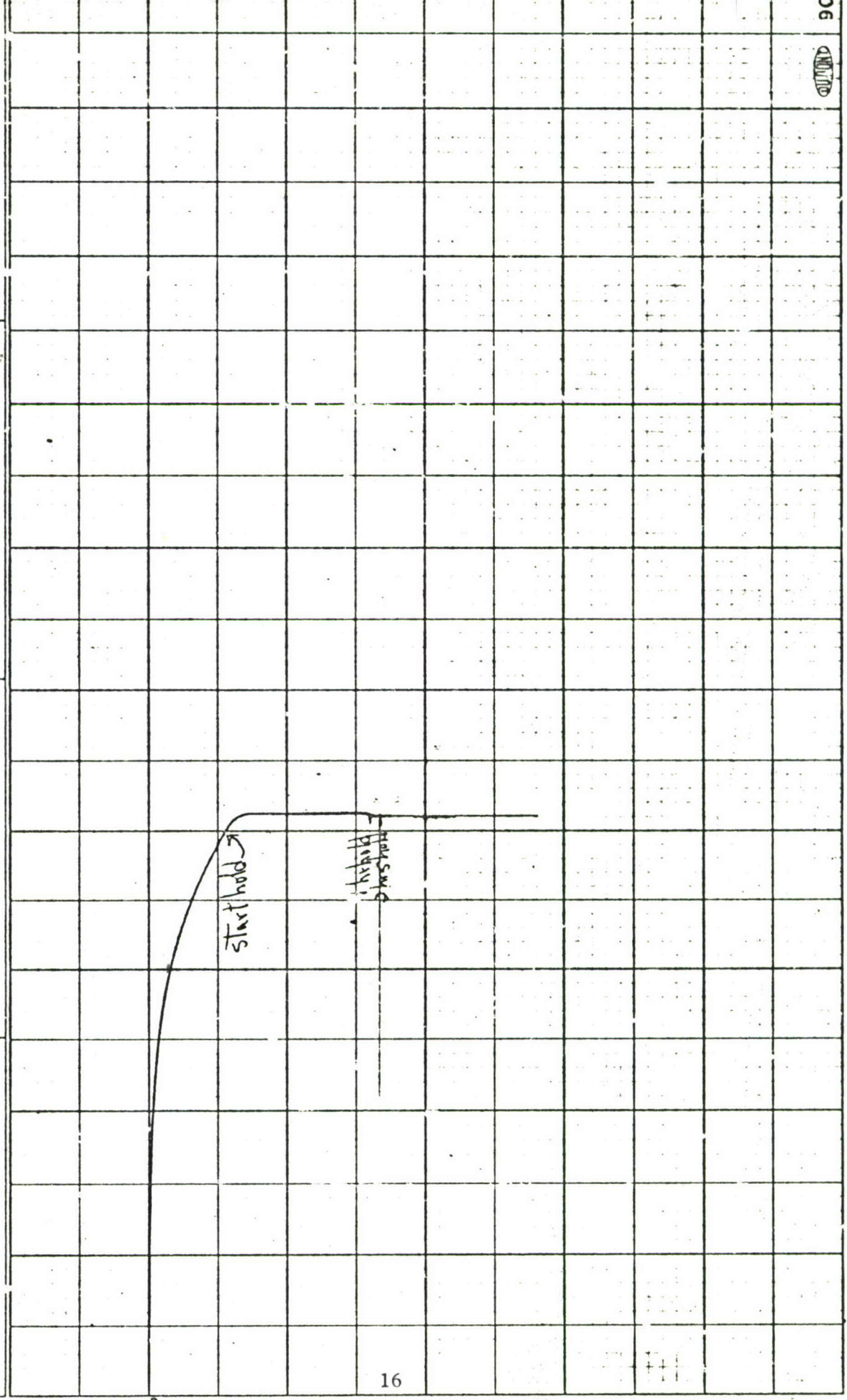


RUN NO. DATE 1/12/77  
 OPERATOR FEW  
 HEATING RATE 15 °C/min  
 ATM. N<sub>2</sub> @ 50 cc/min  
 TIME CONSTANT 1 sec

Y-AXIS  
 SCALE 4  $\frac{\text{mg.}}{\text{inch}}$   
 (SCALE SETTING X 2)  
 SUPPRESSION 0 mg.

X-AXIS  
 TEMP. SCALE 50 °C/inch  
 SHIFT 0 inch  
 TIME SCALE (ALT.)

SAMPLE: Epoxy Resin  
Union Carbide Baktin 1  
 SIZE 216 mg.



T, °C (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES)



SAMPLE: EPOXY RESIN  
UNION CARBIDE #2

SIZE 24.4 mg.

X-AXIS

TEMP. SCALE 50 °C  
inch

SHIFT 0 inch

TIME SCALE (ALT.)

Y-AXIS

SCALE 4 mg.  
inch  
(SCALE SETTING X 2)

SUPPRESSION 0

RUN NO.

DATE 7/23/

OPERATOR DSE

HEATING RATE 15 °C

ATM. N<sub>2</sub> @ 50 cc/min

TIME CONSTANT 1 sec.



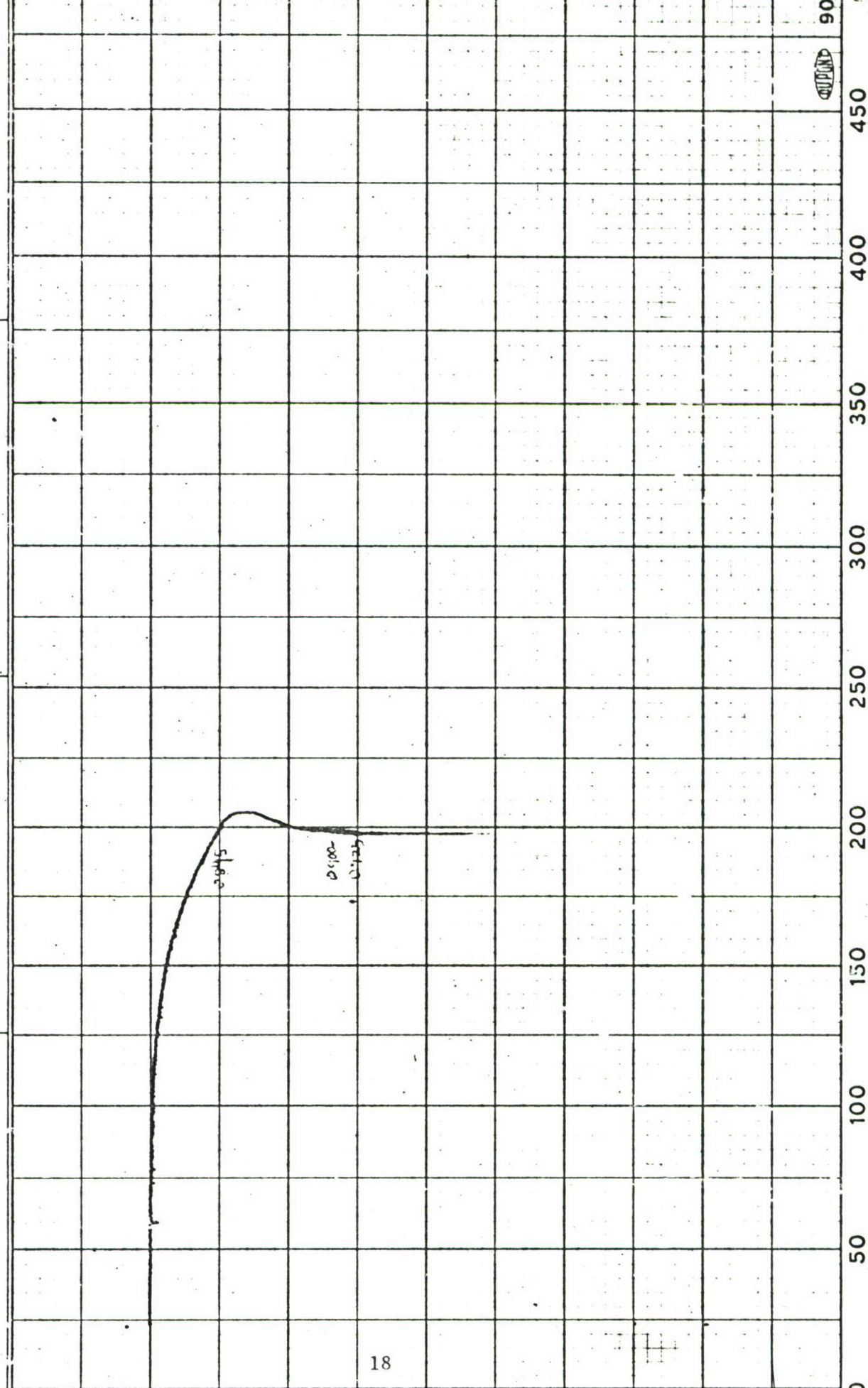
T. °C (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES)

RUN NO. DATE 7/24  
 OPERATOR DSE  
 HEATING RATE 13 °C  
 ATM. N<sub>2</sub> @ 50 cc/min  
 TIME CONSTANT 1 sec

Y-AXIS  
 SCALE 4  $\frac{\text{mg.}}{\text{inch}}$   
 (SCALE SETTING X 2)  
 SUPPRESSION 0 mg.

X-AXIS  
 TEMP. SCALE 50  $\frac{°C}{\text{inch}}$   
 SHIFT 0 inch  
 TIME SCALE (ALT.)

SAMPLE: Union Carbide #3  
 Epoxy Resin  
 SIZE 20.4 mg.



T. °C (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES)



SAMPLE: Limon Carbide #4 Epoxy Resin

SIZE 2.3 mg.

X-AXIS

TEMP. SCALE 0 °C  
SHIFT 0 inch

TIME SCALE (ALT.)

Y-AXIS

SCALE 4 mg.  
(SCALE SETTING X 2)

SUPPRESSION 0 mg.

RUN NO.

DATE 7/27/77

OPERATOR DSE

HEATING RATE 15 °C

ATM. N<sub>2</sub> @ 50 cc/min

TIME CONSTANT 1 sec

02850100150200250300350400450900

T, °C (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES)

1430

1440

1508

1540

19

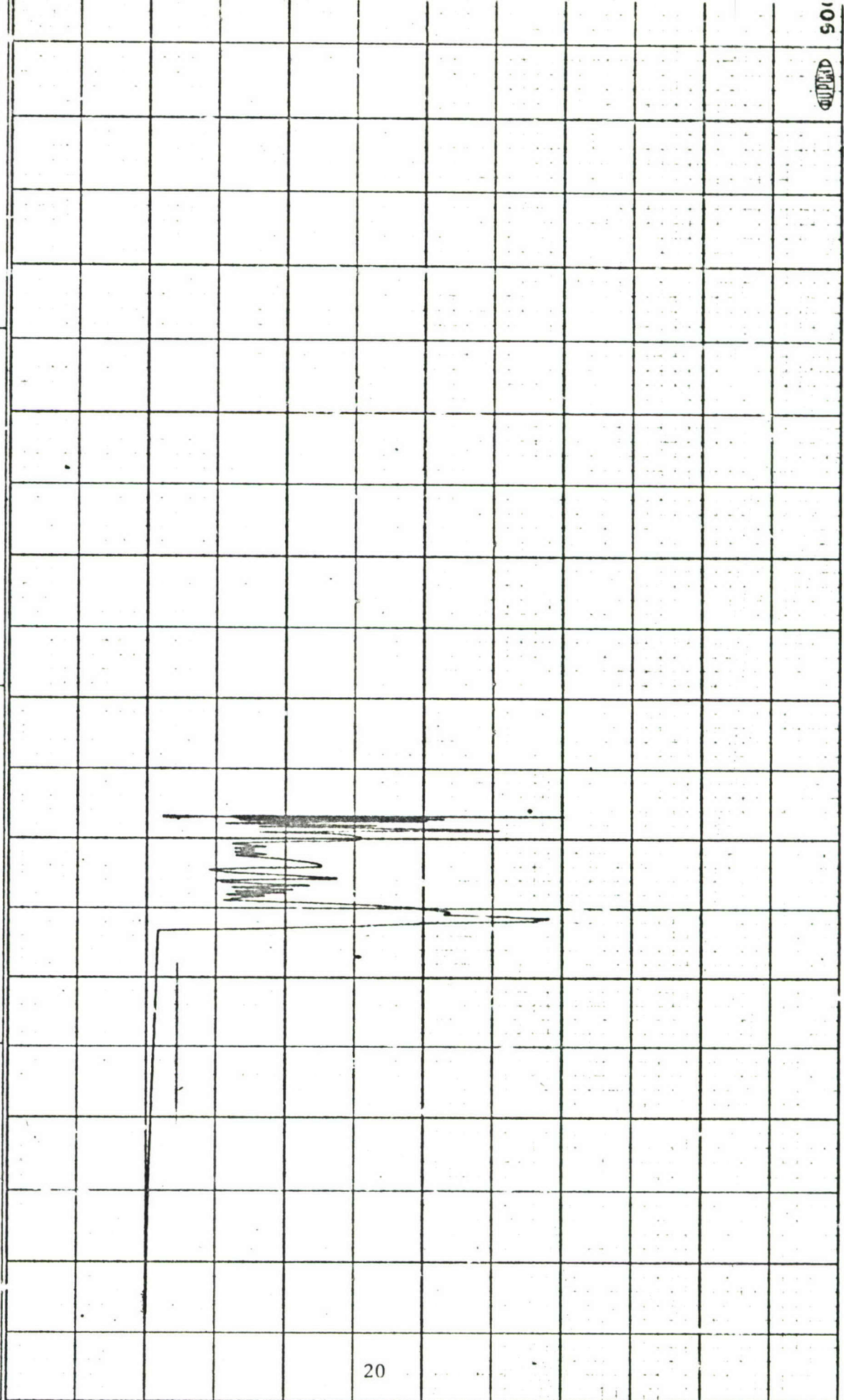
OUTPOND

RUN NO. DATE 7/13/77  
 OPERATOR TJW  
 HEATING RATE 15 °C/min  
 ATM. N<sub>2</sub> @ 50 cc/min  
 TIME CONSTANT 1 sec.

Y-AXIS  
 SCALE 2  $\frac{\text{mg.}}{\text{inch}}$   
 (SCALE SETTING X 2)  
 SUPPRESSION 0 mg.

X-AXIS  
 TEMP. SCALE 50 °C/inch  
 SHIFT 0 inch  
 TIME SCALE (ALT.) \_\_\_\_\_

SAMPLE: Epoxy Resin  
Union Carbide Batch # 5  
 SIZE 21.8 mg.



T, °C (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES)  
 0 50 100 150 200 250 300 350 400 450 500



SAMPLE:

UNION  
carbide #6

SIZE 20.1 mg.

X-AXIS

TEMP. SCALE 50 °C  
inch

SHIFT 0 inch

TIME SCALE (ALT.) 0

Y-AXIS

SCALE 4 mg.  
inch  
(SCALE SETTING X 2)

SUPPRESSION 0 mg.

RUN NO.

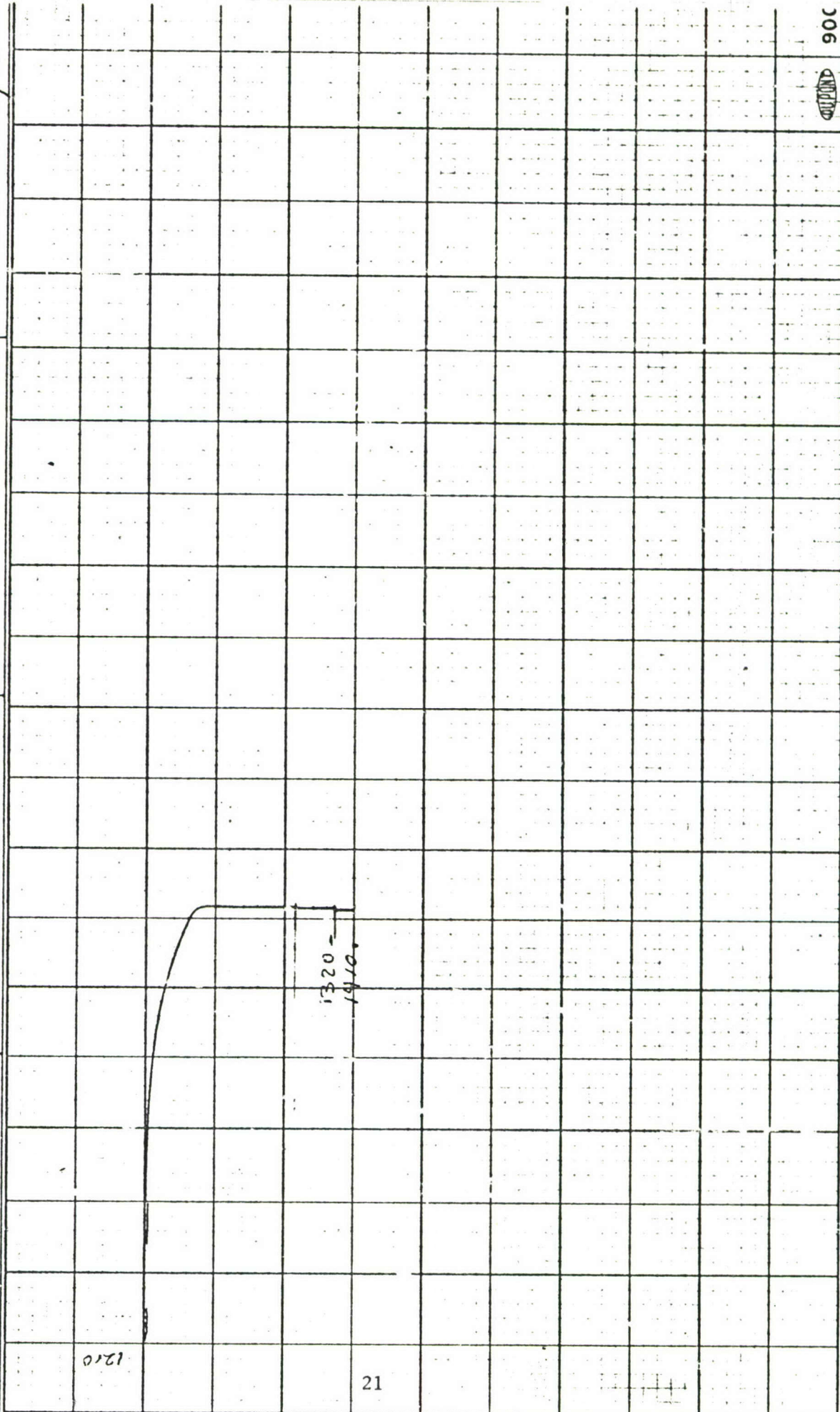
DATE 7/29/71

OPERATOR PSE

HEATING RATE 15 °C

ATM. N<sub>2</sub> @ 50 cc/min

TIME CONSTANT 1 sec.



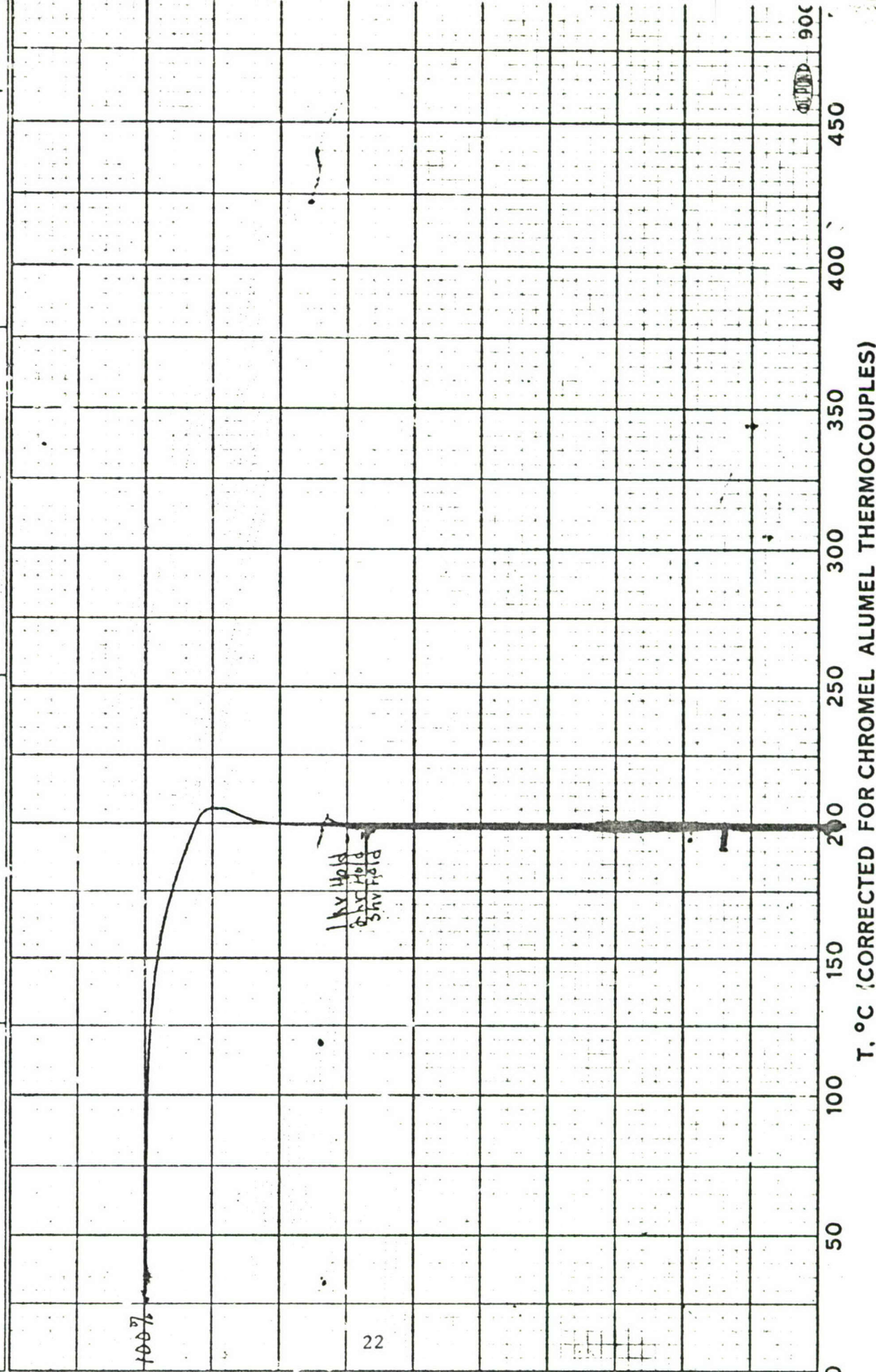
90C

RUN NO. DATE 7/10/70  
OPERATOR TEW  
HEATING RATE 15 °C  
ATM. N<sub>2</sub> @ 50 cc/min  
TIME CONSTANT 1 sec.

Y-AXIS  
SCALE 4  $\frac{\text{mg.}}{\text{inch}}$   
(SCALE SETTING X 2)  
SUPPRESSION 0 mg.

X-AXIS  
TEMP. SCALE 50 °C  
SHIFT 0 inch  
TIME SCALE (ALT.)

SAMPLE: Union Carbide  
Epoxy Resin, Batch # 7  
SIZE 28.0 mg.





SAMPLE: Union Carbide  
Batch # 8

SIZE 23.6 mg.

X-AXIS

TEMP. SCALE 50 °C  
SHIFT 0 inch

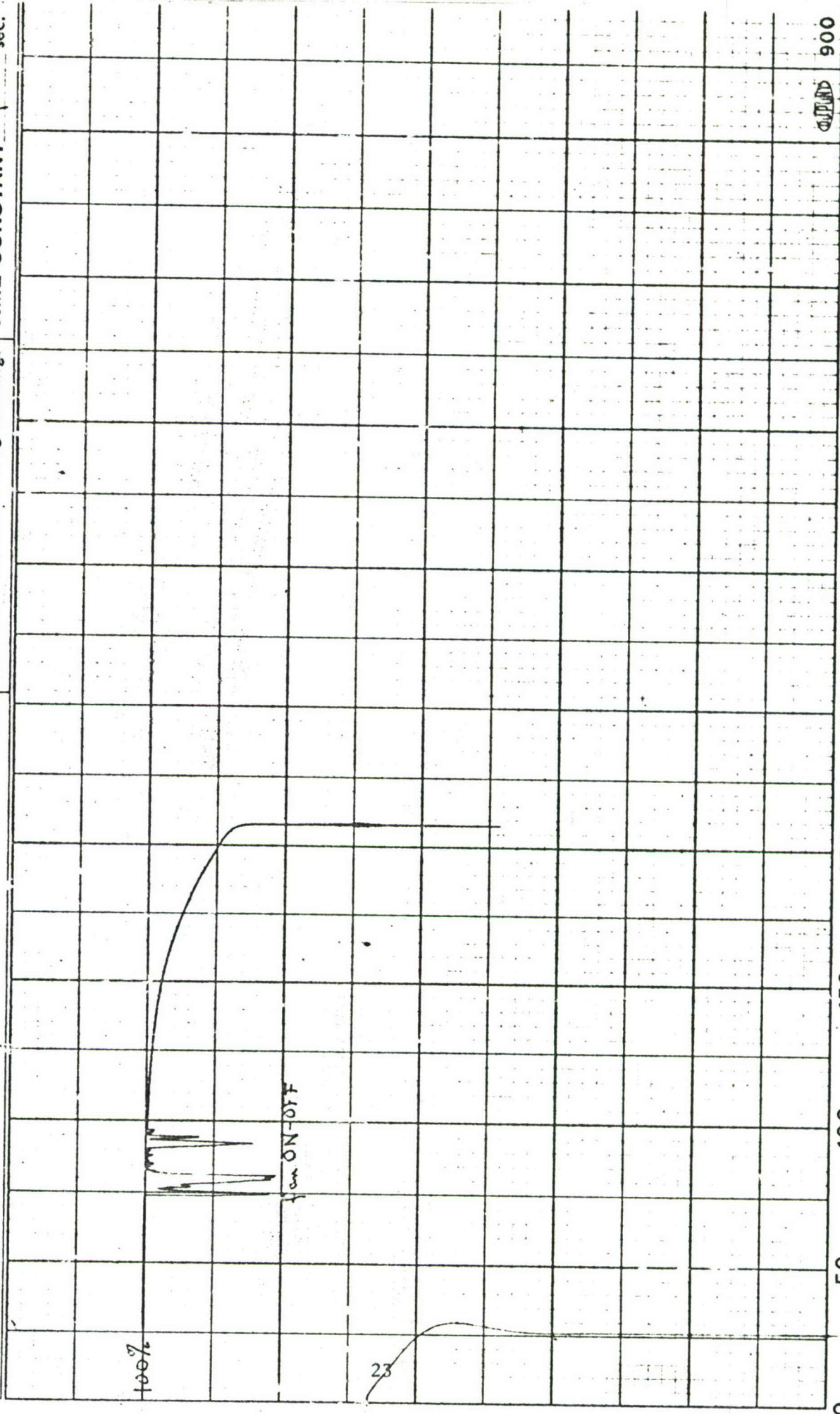
TIME SCALE (ALT.)

Y-AXIS

SCALE 4 mg.  
(SCALE SETTING X 2)

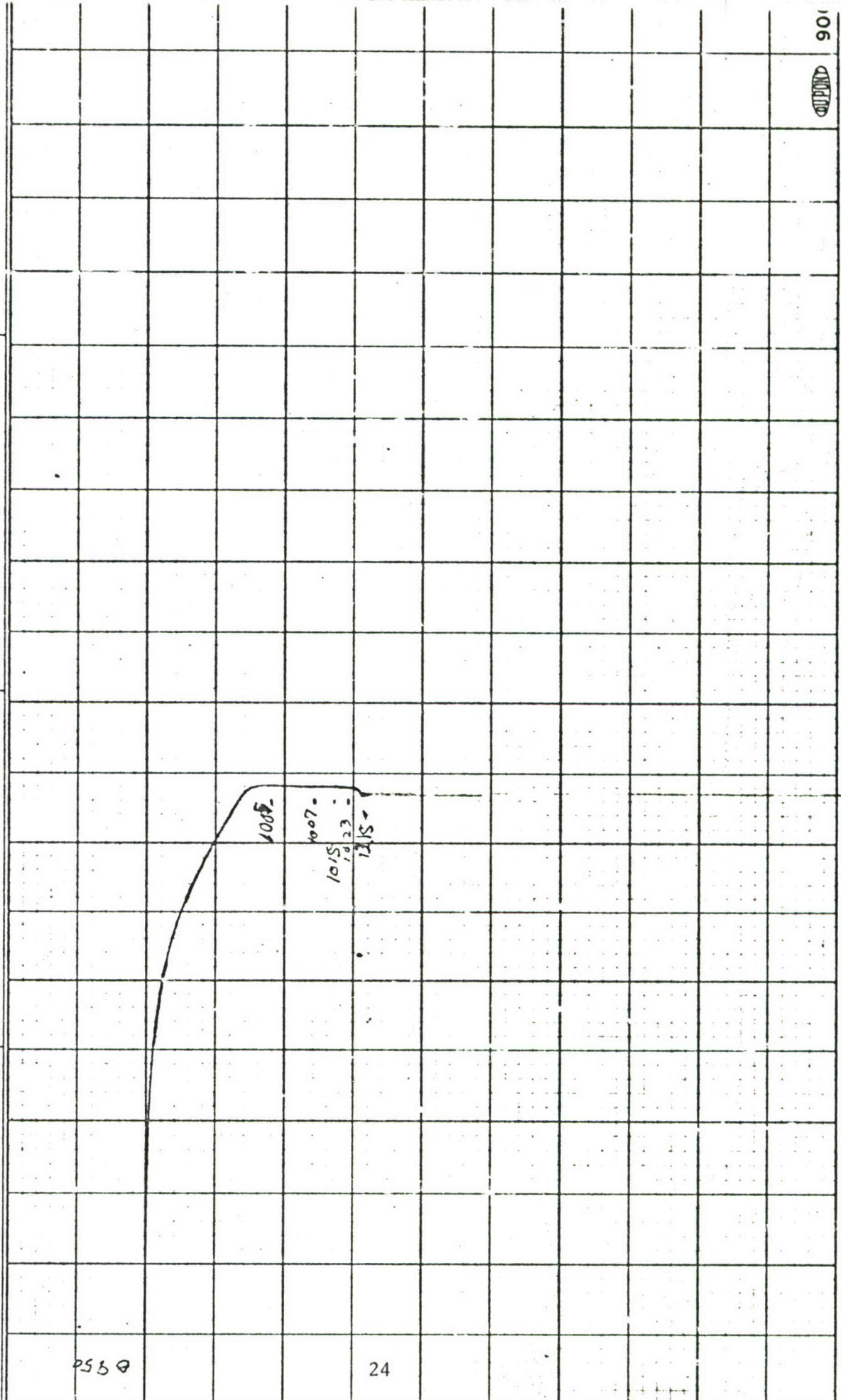
SUPPRESSION 0 mg.

RUN NO. DATE 7/10/70  
OPERATOR TEH  
HEATING RATE 13 °C  
ATM. N<sub>2</sub> @ 50 cc/min  
TIME CONSTANT 1 sec.



T, °C (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES)

|   |   |  |   |  |   |
|---|---|--|---|--|---|
| <b>SAMPLE:</b><br>Union Carbide #9<br><br>SIZE 21.8 mg. | <b>X-AXIS</b><br>TEMP. SCALE 50 °C<br>SHIFT 0 inch<br>TIME SCALE (ALT.) 0 |  | <b>Y-AXIS</b><br>SCALE 4 $\frac{\text{mg.}}{\text{inch}}$<br>(SCALE SETTING X 2)<br>SUPPRESSION 0 |  | RUN NO. DATE 7/30/                                      |
|   |   |  |   |  | OPERATOR DSE  |
|   |   |  |   |  | HEATING RATE 15 °C/min                                  |
|   |   |  |   |  | ATM. N <sub>2</sub> @ 50 cc/min<br>TIME CONSTANT 1 sec. |



T. °C (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES)



SAMPLE: UNION CARBIDE #10

X-AXIS

Y-AXIS

RUN NO.

DATE 7/30/71

TEMP. SCALE 50 °C  
SHIFT 2 inch

SCALE 4 mg.  
inch  
(SCALE SETTING X 2)

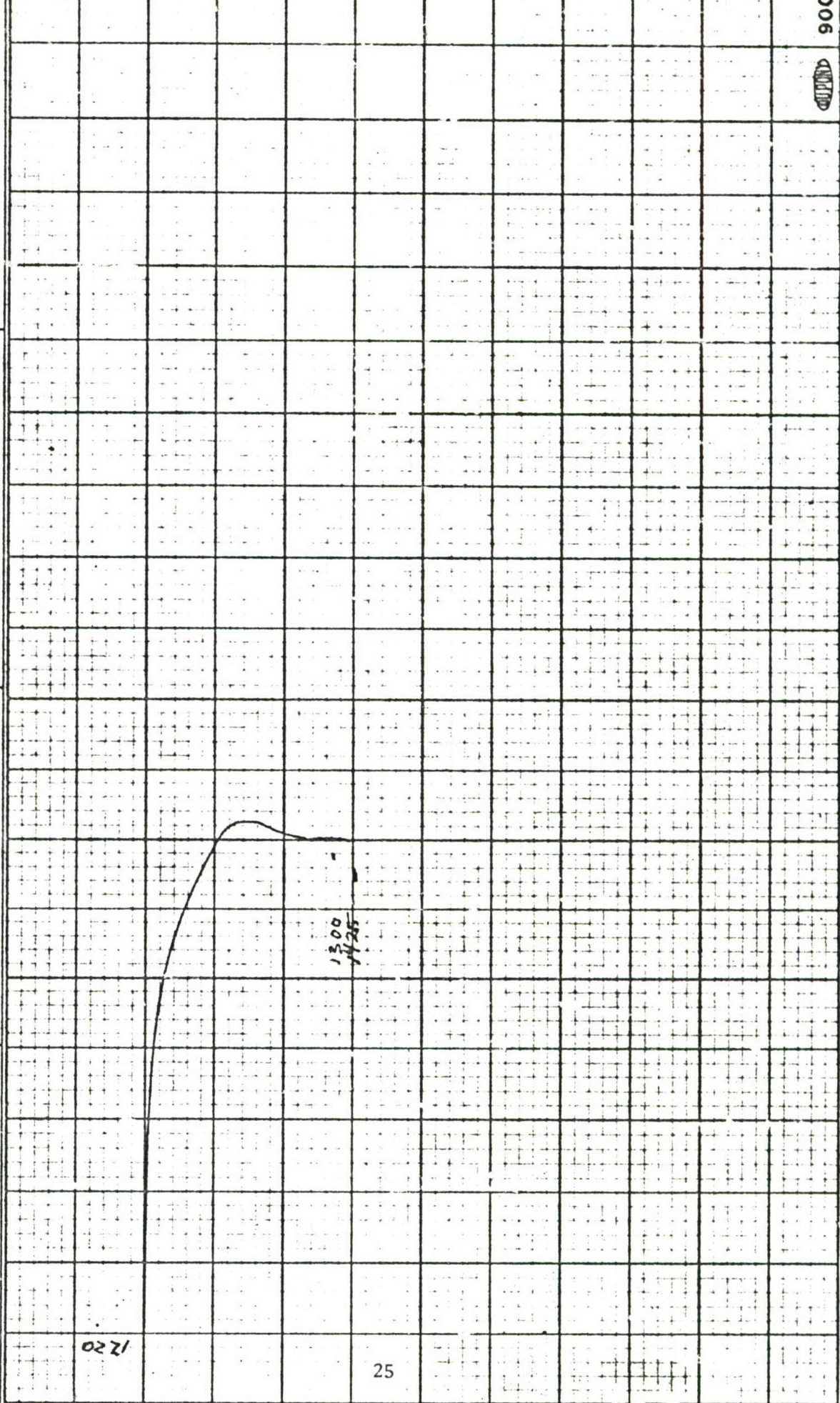
OPERATOR DSE  
HEATING RATE 15 °C

TIME SCALE (ALT.) 0

SUPPRESSION 0

ATM. N<sub>2</sub> @ 50 cc/min  
TIME CONSTANT sec.

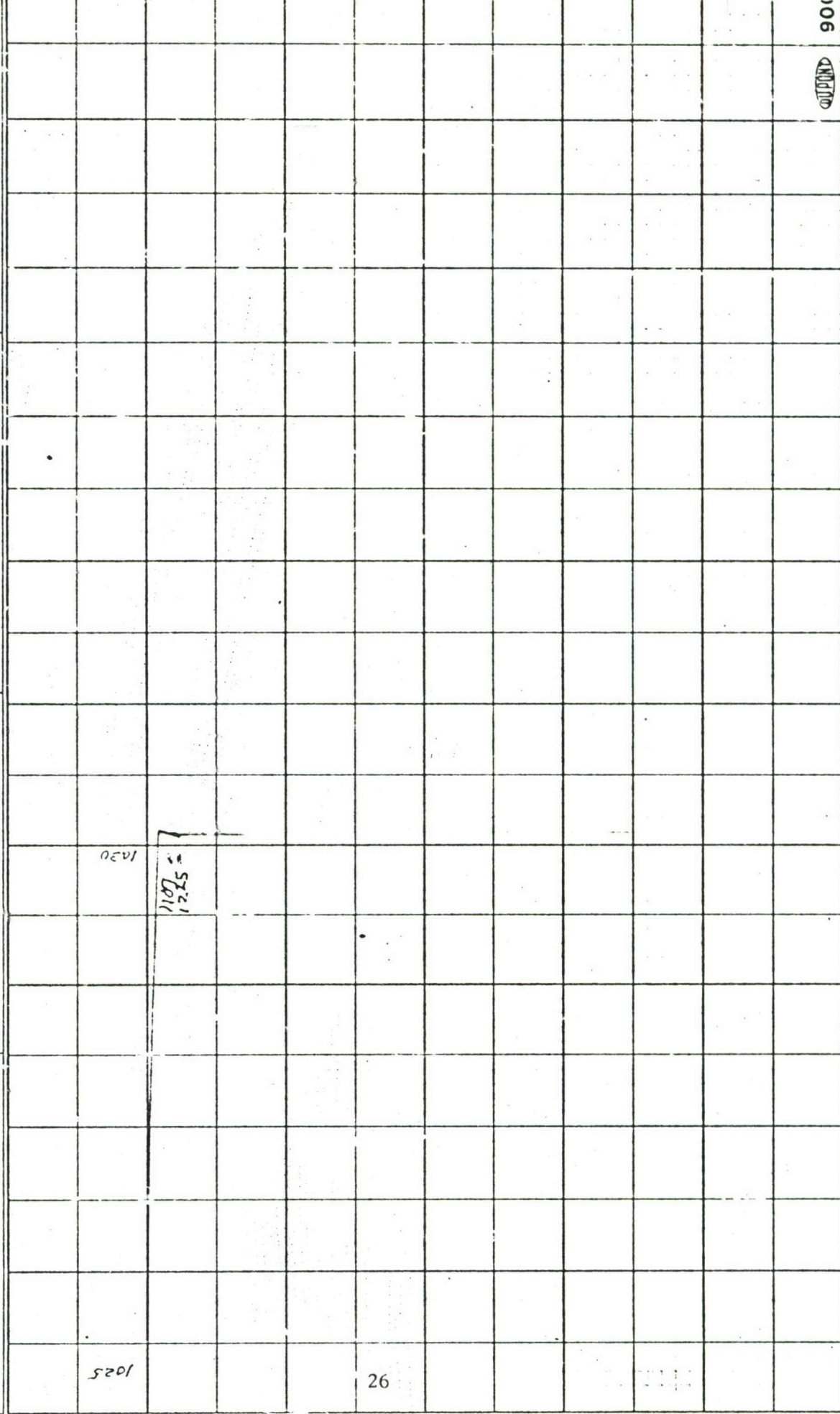
SIZE 21.4 mg.



T. °C (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES)



|  |  |  |   |  |   |
|--|--|--|---|--|---|
| SAMPLE: Dow #1<br>Epoxy Resin<br>SIZE 21.8 mg. | X-AXIS<br>TEMP. SCALE 50 °C<br>SHIFT 0 inch<br>TIME SCALE (ALT.) 0 |  | Y-AXIS<br>SCALE 4 mg.<br>inch<br>(SCALE SETTING X 2)<br>SUPPRESSION 0 mg. |  | RUN NO. DATE 1/28/84<br>OPERATOR DSE<br>HEATING RATE 15 °C<br>ATM. N <sub>2</sub> @ 50 cc/min<br>TIME CONSTANT sec. |
|  |  |  |   |  |   |
|  |  |  |   |  |   |
|  |  |  |   |  |   |
|  |  |  |   |  |   |



T. °C (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES)



RUN NO.      DATE 1/2  
 OPERATOR      DSE  
 HEATING RATE 15 °  
 ATM.  $N_2 @ 50 \text{ cc/min}$   
 TIME CONSTANT      sec

Y-AXIS

---

SCALE 4  $\frac{\text{mg.}}{\text{inch}}$   
(SCALE SETTING X 2)

SUPPRESSION 0 mg.

X-AXIS

TEMP. SCALE 50 °C \_\_\_\_\_ inch

SHIFT 0 \_\_\_\_\_ inch

TIME SCALE (ALT.)

SAMPLE: Dow #2  
Epoxy Resin

SIZE 21.0 mg.

The image shows a full page of graph paper with a grid of squares. In the top right corner, there is a small logo that reads "CARTOON" and the number "9".

Handwritten text and a diagram are located in the lower-left quadrant of the grid:

- A vertical line is drawn across the grid, starting from the bottom and extending upwards.
- At the bottom of this line, the text "115" is written.
- Further up the line, there is a small diagram consisting of a horizontal line segment with a vertical line segment extending upwards from its center. To the right of this diagram, the text "2:26-3:07" is written.
- To the right of the "2:26-3:07" text, there is a small, stylized drawing of a person or figure.

The page number "27" is printed at the bottom center of the grid.

T, °C (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES)

| WEIGHT, mg. | 100 |
|-------------|-----|
|-------------|-----|

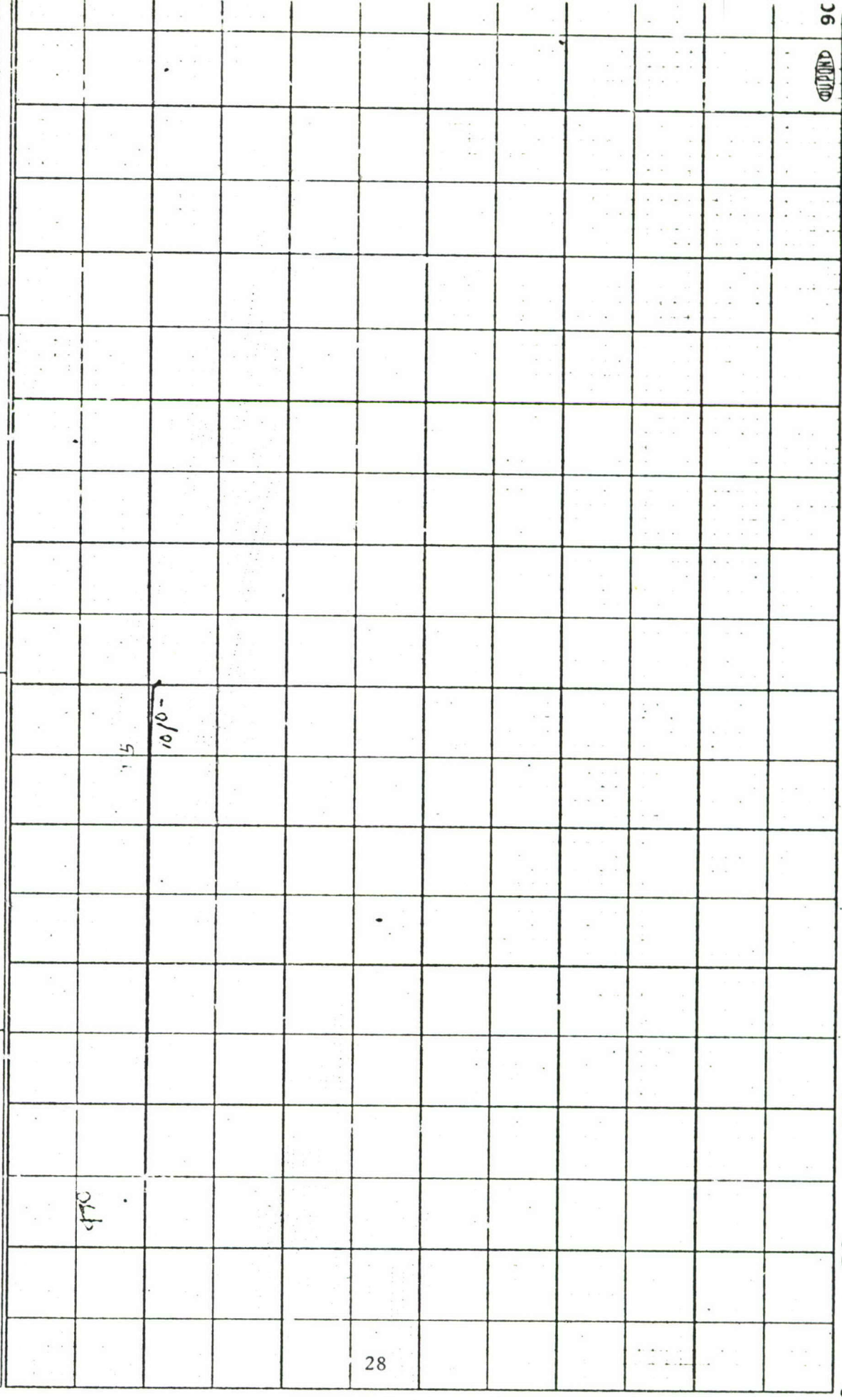
SAMPLE: DOW JF3  
EPOXY RESIN

SIZE 20.6 mg.

X-AXIS  
TEMP. SCALE 0 °C  
SHIFT 0 inch  
TIME SCALE (ALT.)

Y-AXIS  
SCALE 4  $\frac{\text{mg.}}{\text{inch}}$   
(SCALE SETTING X 2)  
SUPPRESSION 0 mg.

RUN NO. DATE 1/27  
OPERATOR DSE  
HEATING RATE 15 °C/min  
ATM. N<sub>2</sub> @ 50 cc/min  
TIME CONSTANT



WEIGHT, mg. 0 50 100 150 200 250 300 350 400 450 90

T, °C (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES)

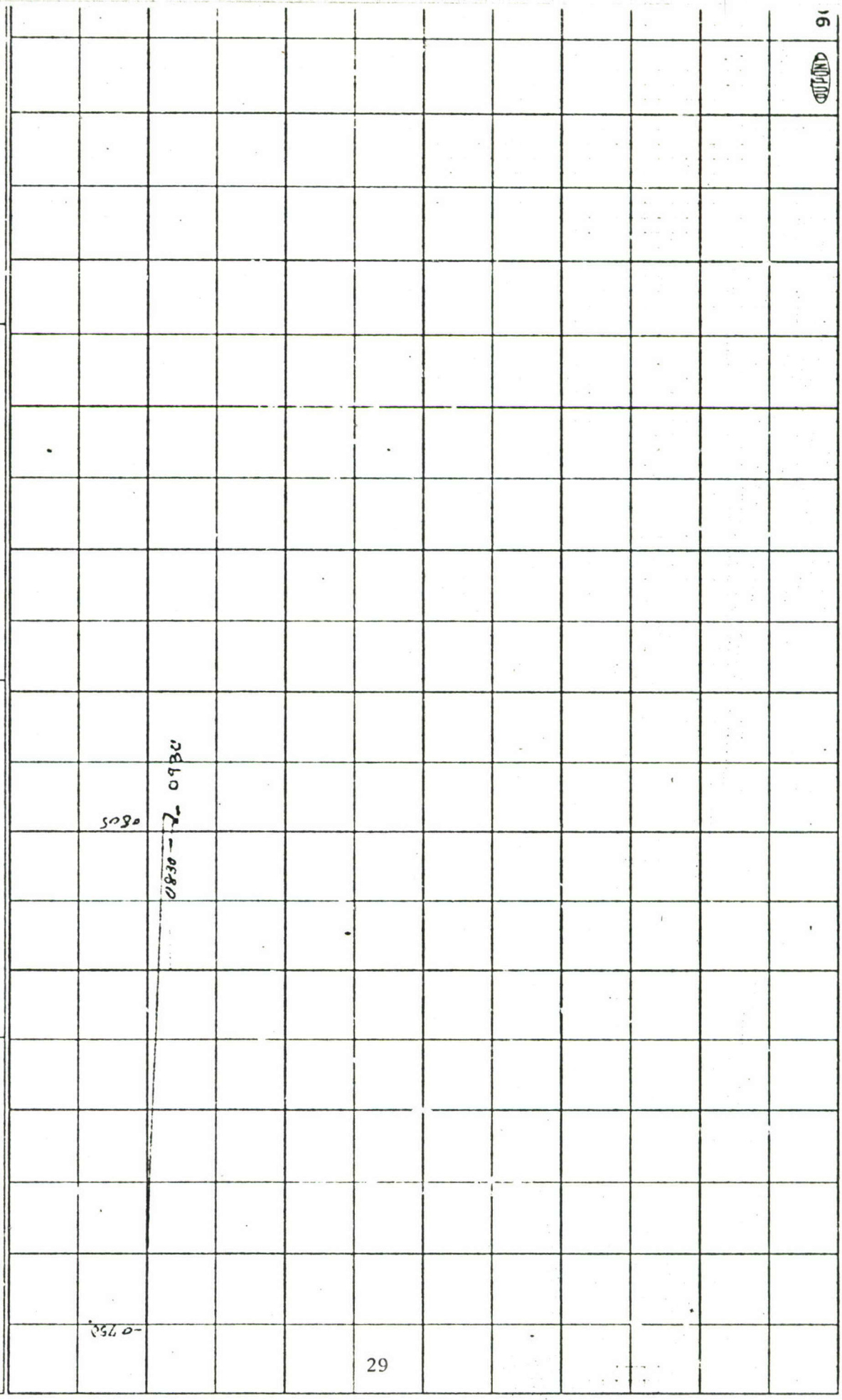


RUN NO. DATE 7/28/58  
 OPERATOR DSE  
 HEATING RATE 15 °C  
 ATM. N<sub>2</sub> @ 50 cc/min  
 TIME CONSTANT 1 sec

Y-AXIS  
 SCALE 4 mg./inch  
 (SCALE SETTING X 2)  
 SUPPRESSION 0

X-AXIS  
 TEMP. SCALE 50 °C  
 SHIFT 0 inch  
 TIME SCALE (ALT.)

SAMPLE: Dow #4 Epoxy Resin  
 SIZE 21.6 mg.



T, °C (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES)

WEIGHT, mg.

SAMPLE:

Dow # 5

SIZE 2.2, 3 mg.

X-AXIS

TEMP. SCALE  $^{\circ}\text{C}$   
inch

SHIFT inch

TIME SCALE (ALT.)

Y-AXIS

SCALE  $\frac{\text{mg.}}{\text{inch}}$   
(SCALE SETTING X 2)

SUPPRESSION

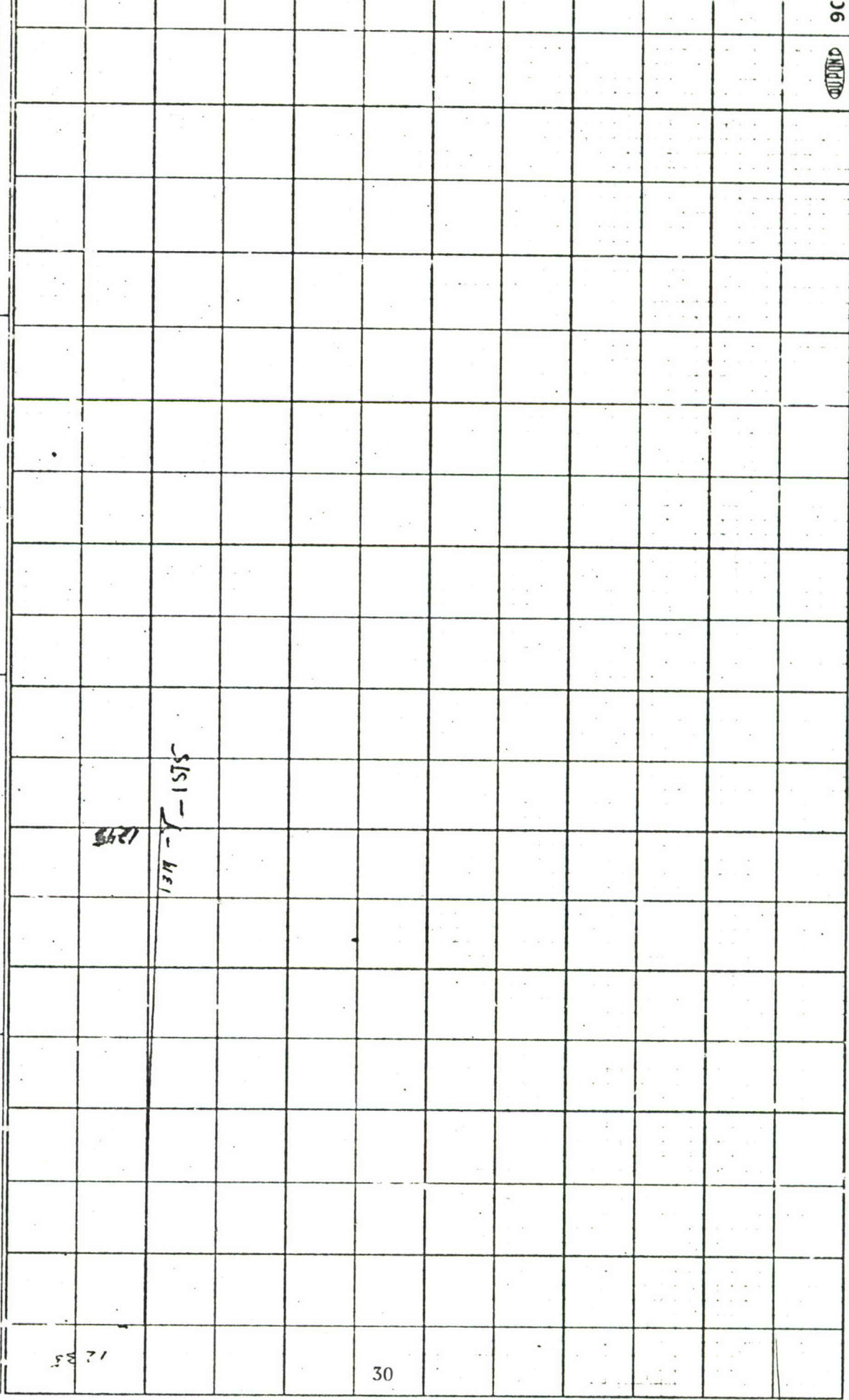
RUN NO. DATE

OPERATOR

HEATING RATE  $^{\circ}\text{C}$   
m

ATM.

TIME CONSTANT sec



T,  $^{\circ}\text{C}$  (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES)

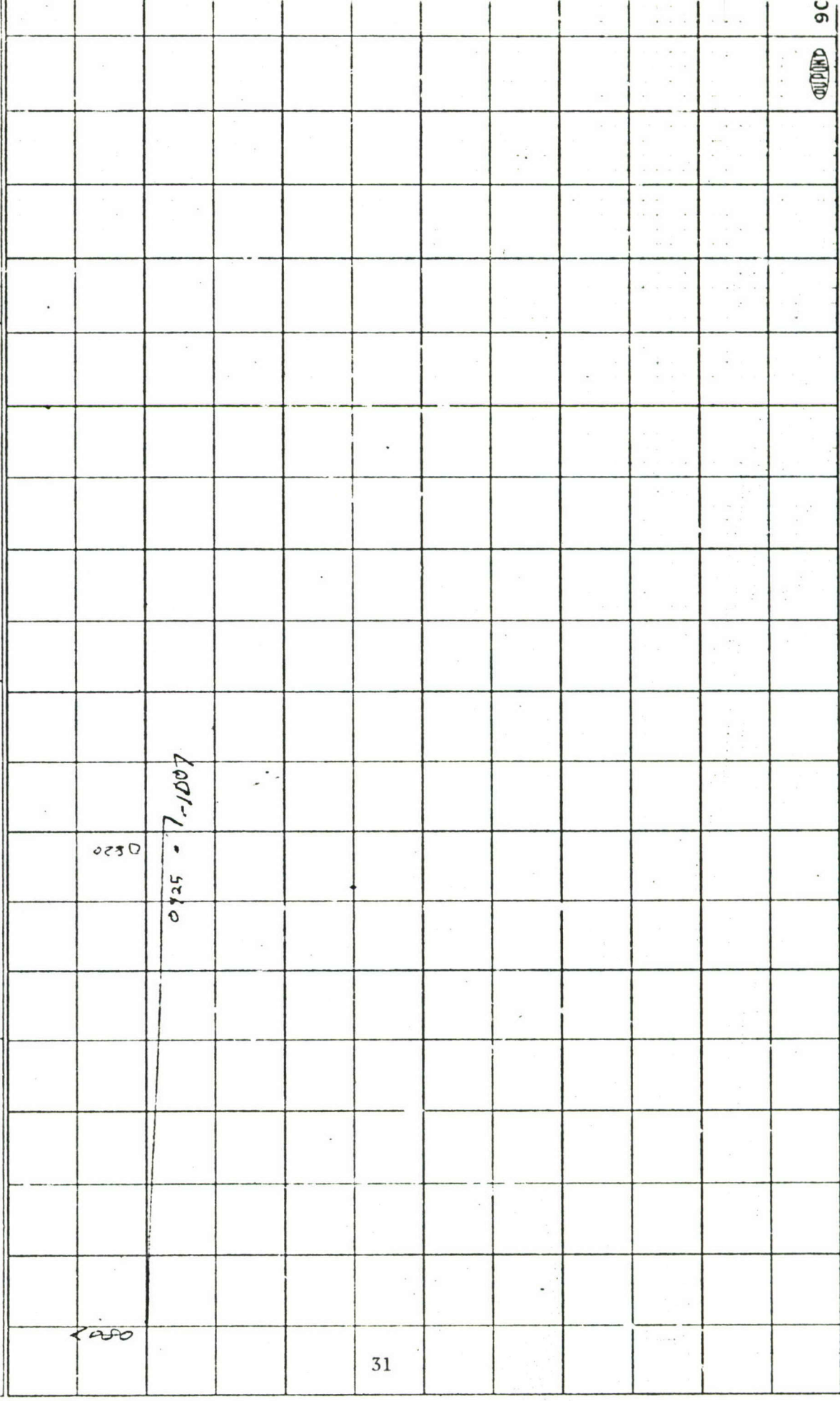


RUN NO. DATE 7/29/71  
 OPERATOR DSE  
 HEATING RATE 15 °C  
 ATM. N<sub>2</sub> @ 50 cc/min  
 TIME CONSTANT 1 sec

Y-AXIS  
 SCALE 4  $\frac{\text{mg.}}{\text{inch}}$   
 (SCALE SETTING X 2)  
 SUPPRESSION 0 mg.

X-AXIS  
 TEMP. SCALE 50  $\frac{^{\circ}\text{C}}{\text{inch}}$   
 SHIFT 0 inch  
 TIME SCALE (ALT.) 0

SAMPLE: Dow #6  
 Epoxy Resin  
 SIZE 21.4 mg.



9C

T. °C (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES)

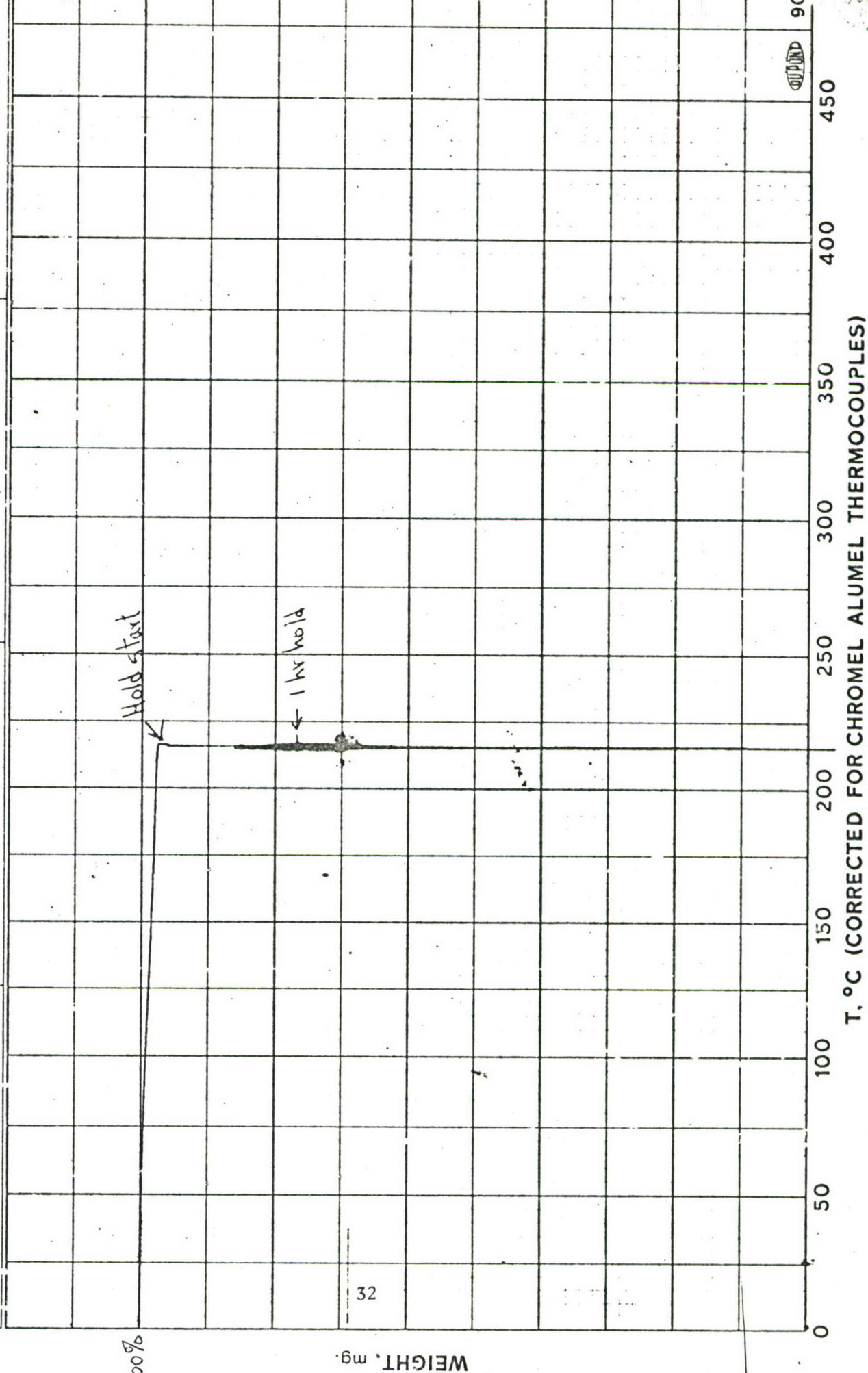
WEIGHT, mg.

RUN NO. DATE 7/9/71  
 OPERATOR TEW  
 HEATING RATE 15  
 ATM. N<sub>2</sub> @ 50 cc/min  
 TIME CONSTANT 1 sec

Y-AXIS  
 SCALE 4 mg.  
 inch  
 (SCALE SETTING X 2)  
 SUPPRESSION 0 mg.

X-AXIS  
 TEMP. SCALE 50 °C  
 inch  
 SHIFT 0 inch  
 TIME SCALE (ALT.)

SAMPLE: Cured Epoxy Resins  
Dow, Batch #7  
 SIZE 22.0 mg.



T, °C (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES)



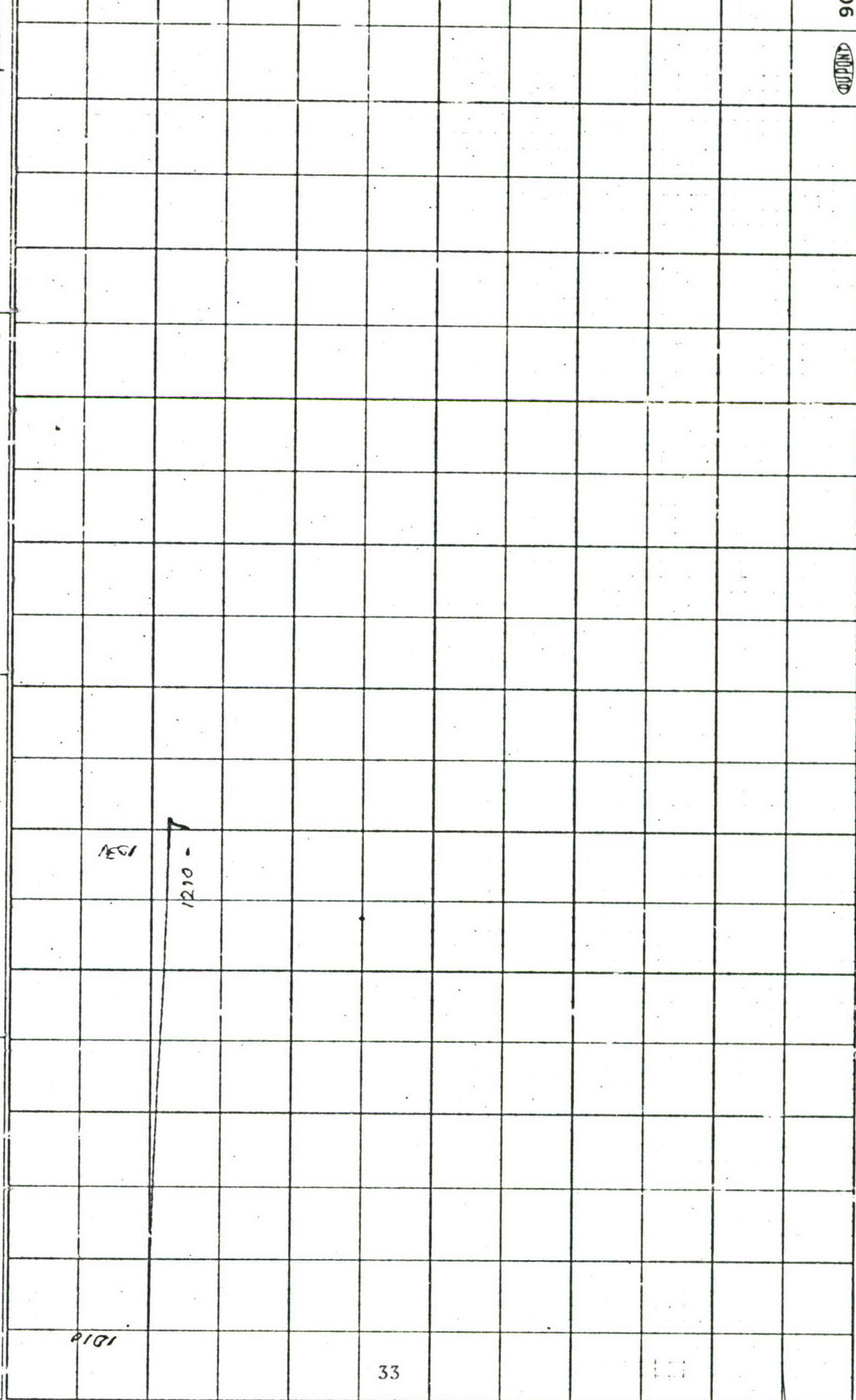
SAMPLE: Dow #8 Epoxy Resin

SIZE 20.6 mg.

X-AXIS  
TEMP. SCALE 50 °C  
SHIFT 0 inch  
TIME SCALE (ALT.) 0

Y-AXIS  
SCALE 1 mg.  
(SCALE SETTING X 2)  
SUPPRESSION

RUN NO. DATE 7/24/71  
OPERATOR DSE  
HEATING RATE 15 °C  
ATM. N<sub>2</sub> @ 50 cc/min  
TIME CONSTANT 1 sec



WEIGHT, mg. 33

T. °C (CORRECTED FOR CHROMEI ALUMEL THERMOCOUPLES)

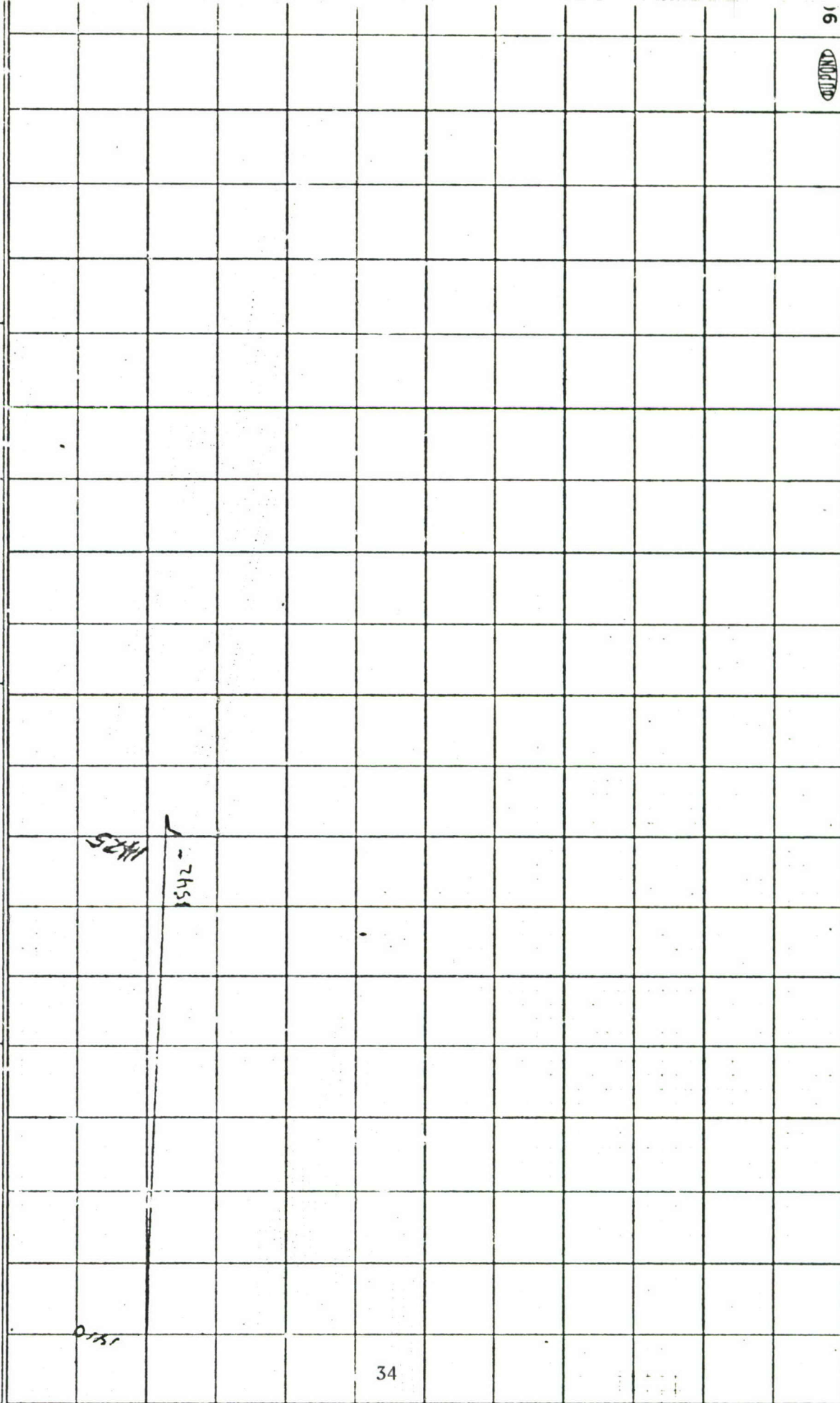
90

RUN NO. DATE 7/29  
OPERATOR DSE  
HEATING RATE 15 °C  
ATM. N<sub>2</sub> @ 50 cc/min  
TIME CONSTANT 1 sec

Y-AXIS  
SCALE 4  $\frac{\text{mg.}}{\text{inch}}$   
(SCALE SETTING X 2)  
SUPPRESSION 0

X-AXIS  
TEMP. SCALE 50  $\frac{^{\circ}\text{C}}{\text{inch}}$   
SHIFT 0  
TIME SCALE (ALT.) 0

SAMPLE: Dow # 9  
EPOXY RESIN  
SIZE 23.4 mg.



WEIGHT, mg. 34

T. °C (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES)

0 50 100 150 200 250 300 350 400 450

90



RUN NO. DATE 7/30/77  
 OPERATOR DSE  
 HEATING RATE 15 °  
 ATM.  $N_2$  @ 50 cc/min  
 TIME CONSTANT 1 sec

Y-AXIS

SCALE 4 mg.  
inch  
(SCALE SETTING X 2)

SUPPRESSION 0 mg.

X-AXIS

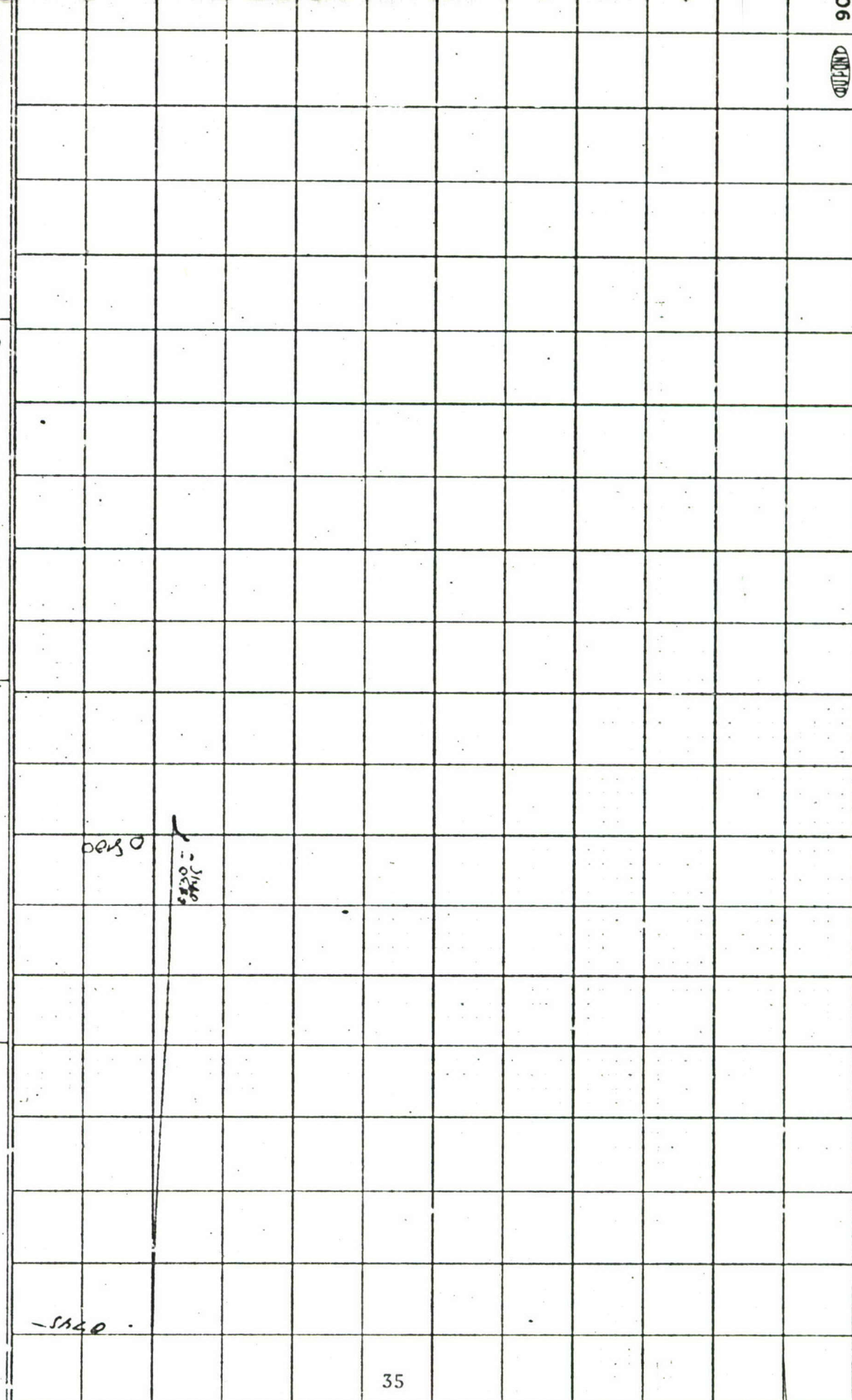
TEMP. SCALE 50 °C

SHIFT 0 inch

TIME SCALE (ALT.) 0

SAMPLE: Dow #10  
Epoxy  
Resin

SIZE 20.6 mg.



| T. °C (CORRECTED FOR CHROMEL ALUMEL THERMOCOUPLES) |     |
|--|-----|
| 50   | 450 |
| 100  | 400 |
| 150  | 350 |
| 200  | 300 |
| 250  | 250 |
| 300  | 200 |
| 350  | 150 |
| 400  | 100 |
| 450  | 50  |

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## 13. ABSTRACT

The material used as a binder in the pyrotechnic compositions (candles) of Mk 24 and Mk 45 Aircraft Parachute Flares, since the 1968 conversion from Laminac to epoxy, has been procured on a sole-source basis from the Dow Chemical Company. A thorough analysis of all pertinent properties of an epoxy produced by Union Carbide Corporation has demonstrated that this material is, in all significant respects, as good as that obtained from Dow. This report recommends that Union Carbide Corporation be approved as an alternate supplier for the epoxy used in these flare candles.



| 14. KEY WORDS  | LINK A |    | LINK B |    | LINK C |    |
|--|--------|----|--------|----|--------|----|
|  | ROLE   | WT | ROLE   | WT | ROLE   | WT |
| Epoxy Flare Binder<br>Pyrotechnic Composition Binder<br>Flexibility<br>Nonreactive Diluent<br>Migration<br>Moisture Absorption |        |    |        |    |        |    |